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GROW MORE VEGETABLES WITH LESS WATER: SPRAY VERSUS DRIP

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ABSTRACT

Experimental data collated in the field under current production methods for lettuce in southern Victoria indicate the same crops can be grown using subsurface drip irrigation compared to spray irrigation with a mixture of recycled water and river water. Subsurface drip irrigation used approximately half the water and up to 33% less fertilizer. These saving can be achieved relatively easily with a subsurface drip irrigation system. However, there are other advantages and disadvantages that need to be factored into decisions about changing irrigation methods. These experiments were conducted over one growing season (2007/08) and the longer term impacts on soils needs to be assessed with respect to nutrient and salt management. Soil samples from this research are currently being analysed and this data may indicate what long term changes may be.

The next phase of this project is to use data collected from this research and the literature to assess the advantages and disadvantages in using drip irrigation compared to spray irrigation from a practical use, economic, agronomic and environmental perspective; ultimately defining if and when the advantages of changing irrigation practice to subsurface drip irrigation outweigh any disadvantages of this intense horticultural production system.

INTRODUCTION

With the introduction of greywater recycling and water efficient appliances in households, volumes of water recycled from wastewater treatment plants are decreasing in some areas of Australia. This observation highlights that even recycled water is a limited resource and needs to be used efficiently with good irrigation techniques that maximise return and manage relatively higher concentrations of salinity and nutrients in the recycled water.

Drip irrigation offers potential to improve management of recycled water. In some cases, research on drip irrigation techniques has indicated improvements in yield and quality of product, better management of soils (salinity and nutrients), improved economic returns in the mid term, improved water use/efficiency, lower pumping costs, and more efficient use of labour across whole farming operations. This research has assessed surface and subsurface drip irrigation techniques in a range of farming operations (e.g. cane, tomatoes, grapes, onion, avocados - Al-Jamal *et al.* 2001; Assaf *et al.* 1986; Battikhi and Abu-Hammad 1994; Bernstein and Francois 1973; Guidoboni 2006; Gustafson *et al.* 1979; NSW DPI 2006). However, these claims vary depending on the crop grown and management methods used. There are limited data available to vegetable growers to assist with making independent informed decisions as to how or if drip irrigation will improve water use efficiency (\$/ML) and the impact on the day to day management of the vegetable farming operation.

The aim of this research was to determine if the advantages of drip irrigation in vegetable production systems outweighed the disadvantages enough to warrant change from current overhead spray irrigation techniques used in this industry.

RESULTS AND DISCUSSION

Field site

In the intense horticultural production industry lettuce is one of the most salt sensitive vegetables produced. Hence, the advantages of using subsurface drip irrigation to cope with water sources that are near salinity threshold (e.g. recycled water and river water in this case) with lettuce gives a worse case scenario.

The trial site was in Southern Victoria on a brown Sodosol (Isbell 2002), previously known as red-brown earth, which is widely used under many irrigated cereals, pasture and horticultural crops in Australia. The common morphological feature of Sodosols is an abrupt texture change between the A and B horizon and strong dispersion, associated with high sodicity. Sodosols within the study area had 15-25 cm of a neutral acidity ($\text{pH}_{\text{CaCl}_2} = 7.0 \pm 0.1$ – all errors are one standard deviation from the mean), slightly sodic (ESP $9.9 \pm 0.8\%$) light clay topsoil, prone to surface sealing, overlying a neutral ($\text{pH}_{\text{CaCl}_2} = 7.1 \pm 0.1$), strongly dispersive, sodic (ESP $10 \pm 1.3\%$) clay loam subsoil (Field data; Imhof *et al.* 2004). The dispersive nature and massive structure of the B-horizon in Sodosols have been shown to limit root growth in many horticultural crops (Shainberg and Letey 1984).

Experiment

The site consists of three bays (12.9m wide, 89m long) with seven raised beds running in an east west orientation. There was a buffer bay (Bay 2) between the two trial bays (Bay 1 and 3) to minimise spray drift from sprinkler irrigation treatments. Treatment areas were 574 m² each. There were 2 treatments (spray and drip irrigation) replicated (Bay 1 and Bay 3) and 4 blocks (Beds 1, 3, 5 and 7 of each bay) within each treatment; with samples taken in triplicate randomly within each bed. For Crop 2, a third treatment was added of subsurface drip irrigation with 40 cm spacing between drippers in beds 2, 4 and 6 of each bay for the subsurface drip irrigation treatment. The original dripper spacing was 30 cm between drippers.

The experiment compared current practices (overhead spray with impact sprinklers) compared with subsurface dripper line irrigation of lettuce grown between 5th September to 10th November (Crop 1) and 19th December 07 to 7th February 08 (Crop 2). Measurement taken during the growing season for each crop included:

- Continuous monitoring of climatic data (Wind direction, solar radiation, temperature and rainfall);
- Continuous monitoring of soil moisture using TDR sensors in each treatment at (20, 40, 60 cm depths for Crop 1 and 15, 30 and 50 cm for Crop 2);
- Water volumes applied (flow meters were fitted to measure total flow to each drip treatment area. Spray nozzles on all sprinklers in spray treatments were replaced at the beginning of Crop 1, variation in flow rates confirmed at the beginning of each crop (using catch cans and measurement of a 2 hour spray irrigation), and two flow meters attached to individual sprinkler heads in each treatment);
- Fertiliser volumes applied through fertigation were measured weekly and fertiliser application prior to planting measured in the field.
- Soil samples were taken prior to Crop 1 and immediately after harvesting Crop 2. Samples were taken at each sample in triplicate at a depth of 0-30 cm (to capture soil till depth and rooting depth of lettuce);
- Soil samples were analysed for pH, Electrical Conductivity (EC), Exchangeable Sodium Percentage (ESP), and plant available Nitrogen Phosphorous Potassium (NPK); irrigation water quality (EC), Sodium adsorption ratio (SAR), Residual Sodium Carbonate (RSC) and total NPK;
- Water samples were taken mid each growing season for each crop and analysed for electrical conductivity, pH, sodium, magnesium, potassium, sulphur, calcium and carbonates. Limited water quality data was also available from the water supplier
- Crop measurements included:
 - Weekly growth (photographs of each treatments)
 - Weed growth
 - Marketable lettuce heads (assessed as the grower would to supply to supermarkets)

- Head diameter and weight of marketable lettuce heads (allowing calculation of lettuce head density).

For Crop 1, fertiliser use was maintained as per current grower practice and water application was in excess of that calculated from pan evaporation data. The aim of Crop 1 was to change one variable only (i.e. irrigation method). However, irrigation volume was decreased later in the crop as it was clear that excessive water was being applied to these treatments that could reduce yield from waterlogging. For Crop 2, fertiliser application was applied as estimated from soil analysis and crop requirements, and water applied based on climatic conditions and crop requirements.

It should also be noted that all treatments used spray irrigation to establish seedlings planted before subsurface drip irrigation treatments were imposed (spray irrigation establishment times were 2 weeks for Crop 1 and 1 week for Crop 2).

Water use

For Crop 1, subsurface drip irrigation averaged 56% less water used compared to spray irrigation (Figure 1). For Crop 2, Drip 30 (30 cm spacing) used an average 43% less water than spray irrigation and Drip 40 (40 cm spacing) used 28% less water than spray irrigation.

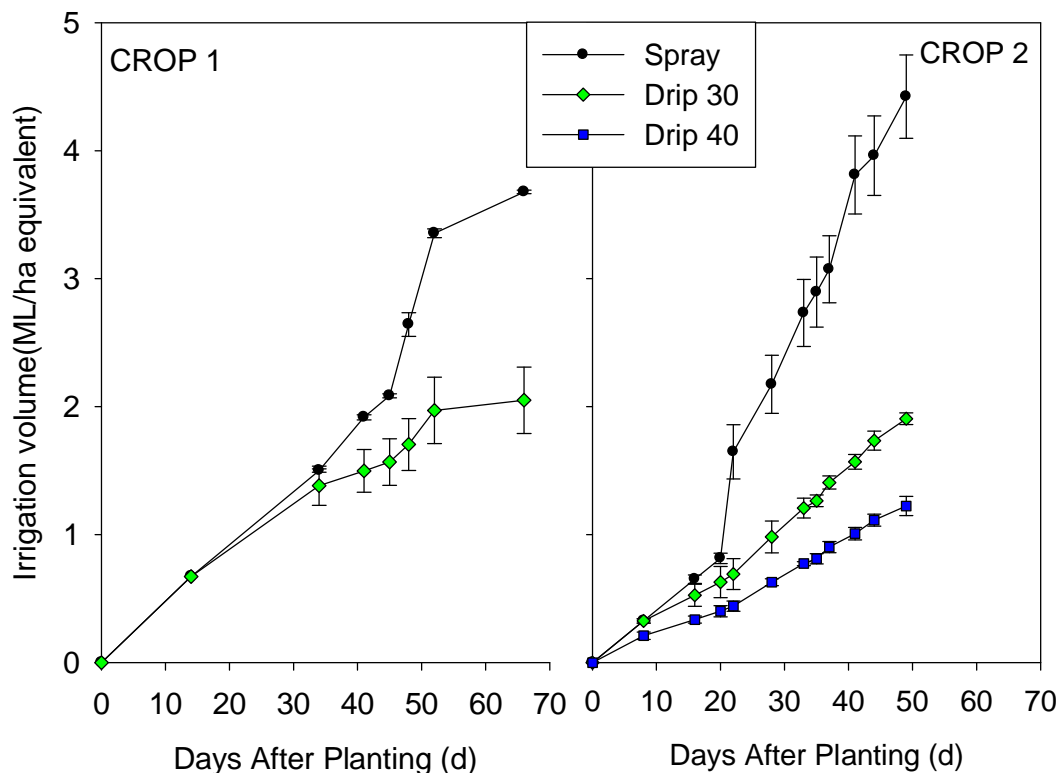


Figure 1 Water use for Crop 1 and Crop 2 for spray and subsurface drip irrigation systems.

Lettuce suitable for market

Harvest data for Crop 1 indicated that a significantly high number of plants were suitable for market when grown in the spray irrigation treatment (Figure 2). Observations during data collection at harvest indicated that was due to a higher number of plants in the subsurface drip irrigation treatment not turning leaves in and forming solid hearts in the lettuce, which was probably due to the excessive fertilizer applied in the subsurface drip treatment. These data indicated that water volumes and fertilizer application needed adjustment to maximize the number of lettuce suitable for market at harvest when changing from spray irrigation to drip irrigation.

For Crop 2, water and fertilizer was optimized for drip irrigation. These data indicate that with 45% less water and up to 33% less fertilizer can be used to grow an equivalent crop (i.e: N 94%, P 67%, K 71%, Ca 90% of fertilizer applied with spray irrigation) (Figure 3). Additional harvest data will be included in other publications.

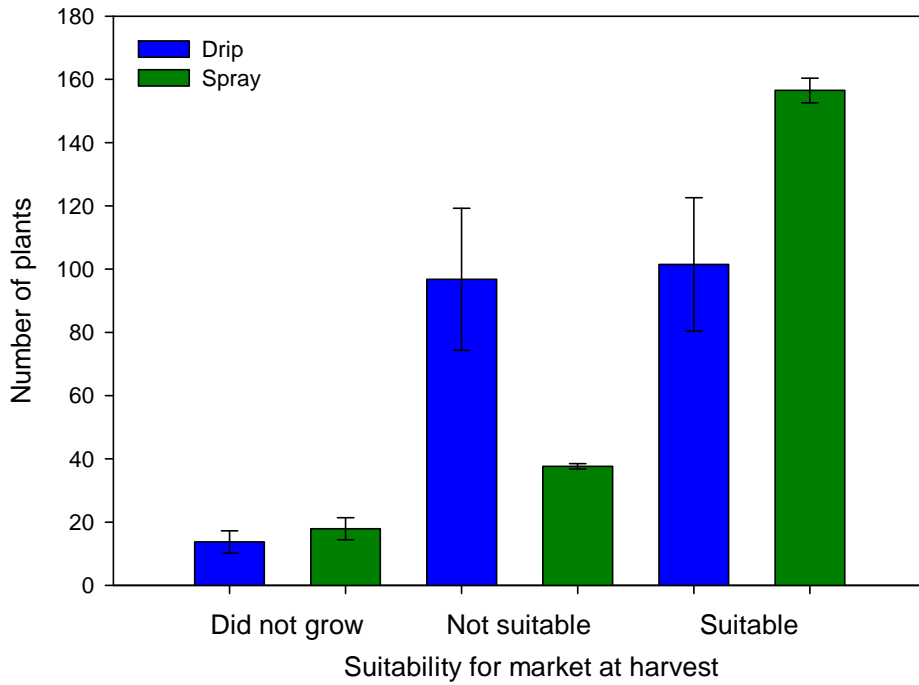


Figure 2 Summary of lettuce measured suitable for market in Crop1.

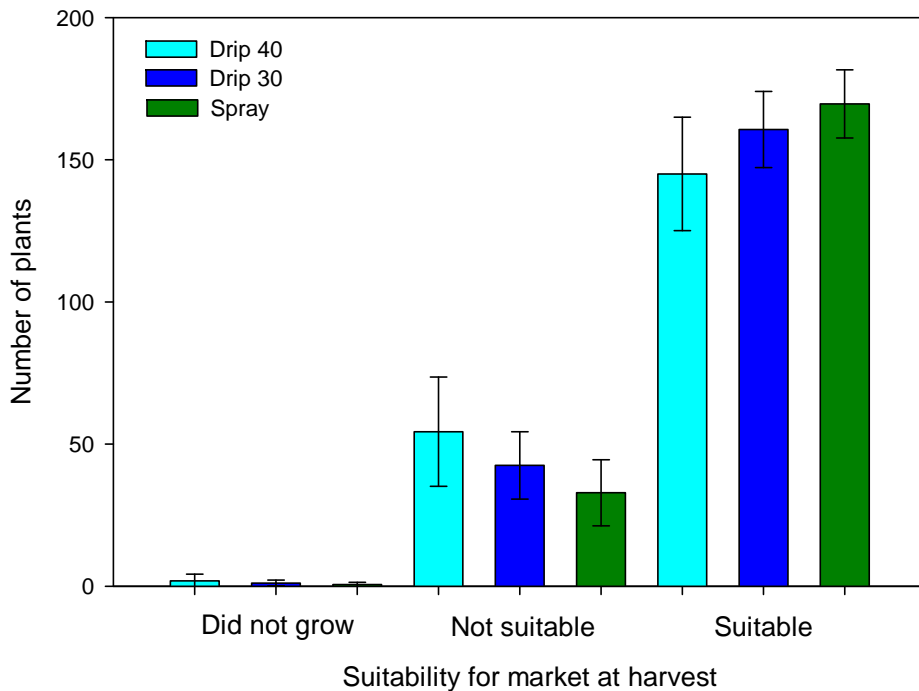


Figure 3 Summary of lettuce measured suitable for market in Crop 2.

CONCLUSIONS

These data indicate that similar lettuce crop harvests can be made by using subsurface drip irrigation by using approximately half the amount of water compared with spray irrigation techniques currently used in the area. Fertiliser savings may also be of benefit.

It was possible to use less water with subsurface drip irrigation compared to spray for several reasons:

- Wind speed at the field site averaged 13.5 ± 7.4 km/hr leading to spray drift off site and increased evaporation;
- Spray irrigation irrigated the whole area (gullies between beds (0.35 m \times 8) and solid set sprinkler rows (0.45 m), where subsurface drip irrigation irrigated the raised growing bed only. (3.25 m of the 12.9 m (25%) is irrigated when using spray irrigation when not required);
- The uniformity of the spray irrigation varied from 25 to 61% of the average (variation calculated on 95 and 5 percentile) application rate depending on wind speed. Therefore to ensure all plants received sufficient water other areas would be over irrigated. Drip irrigation uniformity was estimated to be $\pm 2.4\%$; and
- Irrigation scheduling for spray irrigation was estimated by the grower on previous experience and visual inspection of plants and soil surface, where scheduling of drip irrigation used climatic data and visual inspection involving digging into the soil.

These savings in water use and fertiliser come at a cost and the advantages of a new irrigation method must be weighed up against the costs and disadvantages. Some advantages and disadvantages identified in the research to date are summarised below (Table 1). The next component of this research will attempt to identify the economic savings in changing from drip to spray irrigation.

FUTURE ANALYSIS

Economic assessments are currently underway including:

- Dripper tape – Capital cost/depreciation of layer for laying dripper line, capital/depreciation cost of dripper tape remover, time required for setting up drip tape and removing it, maintenance of dripper line (fixing leakages);
- Pumping requirements (pump capital and running cost, depreciation);
- Operational modifications requirements (i.e. weeding, cleaning, harvestability, accessibility);
- Changes in yield or growing period; and
- Water and fertiliser use between treatments.

Soils are currently being analysed and any difference between spray and subsurface drip irrigation will be presented at the Irrigation Australia Conference.

Table 1 Advantages and disadvantages of drip irrigation identified in research to date.

Item	Advantage	Disadvantage
Potential water saving	<ul style="list-style-type: none"> ▪ Application at the root zone ▪ Minimised evaporation losses, ▪ Dry inter-rows, ▪ Accurate depth of watering. ▪ Good scheduling ▪ No losses from over spray or wind drift ▪ If water supplies are limiting the area cropped, area cropped can be increased with water efficiencies ▪ Minimised impact of increasing water costs 	<ul style="list-style-type: none"> ▪ Not familiar with drip irrigation techniques and may over-water as cannot see how wet soil is.
Labour saving	<ul style="list-style-type: none"> ▪ Less tractor time spreading fertilizer ▪ Less hours starting/stopping valves ▪ Less weeds therefore minimal weeding required 	<ul style="list-style-type: none"> ▪ Breakages as a result of operator unfamiliar with dripper system
Potential Pesticide saving	<ul style="list-style-type: none"> ▪ Better pest control as drip does not wash chemical off leaf ▪ Plant leaves not left moist providing micro climates for some pest ▪ Less weed germination and growth 	<ul style="list-style-type: none"> ▪ Cannot apply some pesticides with subsurface drip irrigation and can with spray.
Potential fuel saving	<ul style="list-style-type: none"> ▪ Reduced energy costs due to correct application of water, ▪ Reduced pressure requirement for irrigation system therefore reduced power demand ▪ Less tractor hours, less slip as traffic areas are generally not wet 	
Potential fertilizer saving	<ul style="list-style-type: none"> ▪ Efficient application when applied to root with little wastage ▪ More targeted efficient uptake ▪ Less leaching of nutrients 	<ul style="list-style-type: none"> ▪ Some fertiliser may not be soluble enough to supply with drip irrigation systems and if too concentrated could cause blockages
Potential for better crop quality and yields	<ul style="list-style-type: none"> ▪ Foliar toxicity of slightly saline water applied to plant leaves avoided ▪ Salt accumulating in soil can be leached laterally into the furrow between beds ▪ Better uniformity of crop to enable harvesting all at the same time ▪ Provide an additional barrier of safety if water quality supplied (recycled water or river water) is not fit for the purpose of growing plants eaten fresh. 	
Can drip be used to supply sufficient leaching of salts if required?	<ul style="list-style-type: none"> ▪ Crop 1 indicated this was theoretically possible, soils are currently being analysed. ▪ High frequency drip irrigation reduces the effect of increased salt concentration of the soil solution between irrigations compared to the lower-frequency of surface and sprinkler irrigation 	

Item	Advantage	Disadvantage
Drip may not be suitable for establishment of lettuce	<ul style="list-style-type: none"> Unknown at this stage, however, observations indicate the full soil profile in the raise bed is fully wetted with subsurface drip irrigation. 	<ul style="list-style-type: none"> Spray irrigation may still be required to set seedling in soil
Set up costs		<ul style="list-style-type: none"> Capital cost to purchase tubes, filters, valves, controller, main pipes and fittings
Operating costs	<ul style="list-style-type: none"> Better weed control, so less time required for labour. Less water on tracks, therefore less track maintenance required. Easier access for labour and equipment as water only in beds. 	<ul style="list-style-type: none"> Time required installing and retrieving subsurface drip system for each crop.
Blockages	<ul style="list-style-type: none"> Single use tape used 	<ul style="list-style-type: none"> Additional cost, but recycled
Breaks in drip lines	<ul style="list-style-type: none"> Installed correctly and managed appropriately day to day, limited possibility 	<ul style="list-style-type: none"> If not installed correctly or damaged through weeding or tractor implements then additional labour required and water loss possible.
Frost reduction control questionable	<ul style="list-style-type: none"> Unknown at this stage 	<ul style="list-style-type: none"> Unknown at this stage
Effective for cooling of plants in extremely hot days	<ul style="list-style-type: none"> Yes. Three of the hottest days (>35°C) this year were experienced in Crop 2 just after implementing the subsurface drip irrigation treatment, with no impact on plant survival (Figure 3). 	
Learning a new system	<ul style="list-style-type: none"> Potential benefits and improved risk management as critical control points monitored electronically and can report to base (operator). 	<ul style="list-style-type: none"> Time and effort is required to learn to operate and maintain a new irrigation system. Especially in the first years of operation.

ACKNOWLEDGEMENTS

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